

Control of a Circular Jet

Trushar B. Gohil, Arun K Saha and K. Muralidhar
Department of Mechanical Engineering

Indian Institute of Technology Kanpur, Kanpur 208 016, India

October 18, 2010

Abstract

The present study report direct numerical simulation (DNS) of a circular jet and the effect of a large scale perturbation at the jet inlet. The perturbation is used to control the jet for increased spreading. Dual-mode perturbation is obtained by combining an axisymmetric excitation with the helical. In the fluid dynamics videos, an active control of the circular jet at a Reynolds number of 2000 for various frequency ratios (both integer and non-integer) has been demonstrated. When the frequency ratio is fixed to 2, bifurcation of the jet on a plane is evident. However, for a non-integer frequency ratio, the axisymmetric jet is seen to bloom in all directions.

Fluid jets emerging from a circular tube are commonplace and more so in a variety of applications. The performance of a jet is to be seen in the context where it is put to use. The jet should be highly directional if used as thruster and must spread maximally if used for mixing. Preliminary research shows that forcing clearly leads to large-scale effects in the spatial development and characteristics of the flow field. Under certain perturbation conditions, the outcome of control may result in blooming of the axisymmetric jet. A blooming jet shows axisymmetric spreading in all directions. When the frequency ratio is a non-integer, Lee and Reynolds (1985) experimentally showed how simultaneous axial and orbital excitations can be used to dramatically increase the growth of the jet shear and formation of blooming jet. These effects are demonstrated numerically in the present study. The

simulation uses the MAC (Marker-And-Cell) method based on higher order discretization. These are the 4^{th} order central difference for the viscous terms, a hybrid of 4^{th} and 5^{th} order upwind for the convective terms while the temporal derivative uses a 2^{nd} order Adam-Bashforth scheme. The number of grid points used in the present simulation is $210 \times 276 \times 276$. The Reynolds number based on the maximum incoming velocity and the diameter of the nozzle is fixed at 2000. Dual-mode perturbation is obtained by combining an axisymmetric excitation with the helical.

The spreading of the jet is found to depend solely on the ratio, R_f , between the non-dimensional axial frequency (St_D) and the orbital frequency (St_H). The iso-surfaces of vortical structures (Q -function) have been presented in the videos for the demonstration of bifurcation and blooming phenomena. The jet bifurcates for a frequency ratio of 2 while the formation of the blooming jet with a varying number of branches is possible by changing the frequency ratio away from two, as a non-integer. The details of the study are available in Gohil (2010).

There are two videos uploaded in the arXiv system: one of low resolution (APS_Gohil_Saha_Muralidhar-352x288.mpg; 352x288) and the other, with a high resolution (APS_Gohil_Saha_Muralidhar-720x576.mpg; 720x576)

Reference

1. Lee M. and Reynolds W.C., Bifurcating and blooming jets, Report TF-22, Thermosciences Division, Department of Mechanical Engineering, Stanford University, Stanford, CA 1985.
2. Gohil, T. B., "Control Of Circular And Square Jets Using Large Scale Perturbations: A Numerical Study", Ph.D Thesis, Indian Institute of Technology Kanpur, Kanpur, India, 2010.